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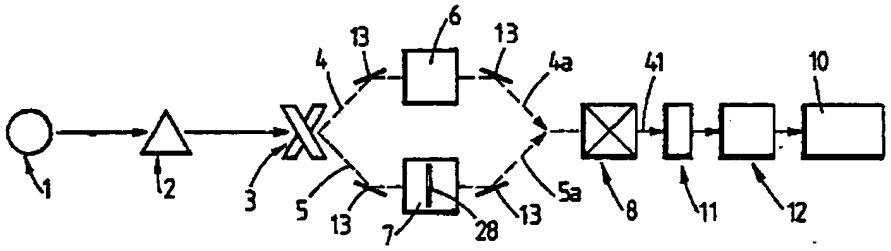

(57) Abstract

A device for exactly determining the colour of a dental prosthesis to be applied, or of the material to be used in dental pluggings, so as to make it perfectly identical to the colour of the patient's teeth. Comprising a light source (1), which sends light rays over a monochromator (2), which, by means of an optical switcher or chopper (3), separates the monochromatic light rays into at least two parallel circuits (4, 4a, 5, 5a), the one (4, 4a) including a housing or cell (6) for at least one of the patient's teeth (9), the other, (5, 5a), comprising a reference cell (7), which includes a white-coloured reference sample (28). Said circuits head up at a device (8) that detects and compares the rays coming from cell (7) and those that have passed through cell (6) and the tooth or teeth (9), providing a sequence of signals that are applied to a detector (8), which are then duly amplified and applied to a digital-analogical convertor (12), which is hooked up to a data processor or computer (10), which provides the coded identification data on the colour as identified.

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A SPECTRUM-PHOTOMETER DEVICE FOR EXACTLY DETERMINING THE COLOUR OF A DENTAL PLATE AND OF DENTAL PLUGGINGS

The invention concerns a spectrum-photometer device that can be used by dental medical doctors and by dental surgeons or by dental technicians working in dental laboratories to exactly determine the colour of one or more of the patient's teeth, so as to be able to obtain a dental prosthesis or dental fillings/identical in colour to the natural colour of the patient's teeth.

Up until now this identification of the colour was done in a very approximative manner by placing in close proximity to the patient's teeth a support bearing a series of teeth of various colours and estimating, by eye, but with a very limited approximation to the actual colour, the colour of the prosthesis tooth or teeth being considered nearest to the colour of the natural teeth, either to make invisible dental fillings or to obtain a partial reconstruction of a natural tooth.

This invention envisions a device for detecting, immediately and with the greatest precision, the colour of the patient's teeth, which device includes as its principal part a UV/VIS spectrum-photometer of any suitable kind, a device that in itself is already known, but that, according to this invention, is outfitted with special means whose purpose is the specific one

indicated above.

As is known, spectrum-photometers can detect the colour of an object or of a part of an object with extreme speed and reliability, making no mistakes.

The device comprises substantially a light source and means for obtaining a monochromatic pencil of rays that are made to pass through two parallel circuits. In one of these said two circuits there is a housing within which at least one tooth may be inserted, whose colour is to be measured, and in the other circuit a cell is inserted, which contains a reference white sample, from which an information signal is generated for making the comparison of the two colours picked up, with signals of the various UV/VIS wave lenghts.

The two circuits channeling the beam of monochromatic rays that has crossed over the tooth and the one that has crossed over the sample contained in the reference cell, end up at a device that compares the two signals and provides, in code form, visual or printed information of the colour detected, after processing the input data.

The invention envisions that the cell, assigned to housing the tooth or teeth being observed, be perfectly screened from the entrance of any possible external light, as well as from moisture present in the mouth, which would prejudice the exactness of the colour reading.

This and other of the invention's characteristics shall

become more evident from the description, that follows, of several forms in which it may be ralized, reference being made to the attached drawings, in which:

Fig. 1 is a schematic of the main components of the material device of the invention;

Fig. 2 is a variation of the schematic of Fig. 1;

Figs. 3 and 4 display, in perspective view and in cross-section, respectively, a cell for the insertion of one or more teeth side by side;

Figs. 5, 6, 7A, 7B display in perspective and in plan another variation of the detection cell;

Figs. 8 and 8A display in cross section and in perspective view respectively, another variation of the detection cell;

Figs. 9A, 9B display schematic perspective view of two other variations of the detection cell;

Fig. 10 shows a perspective view of a cell reduced down just to the bar of some flexible material, acting as a shutter for the light, having a longitudinal groove that can deform when the teeth are inserted;

Fig. 11 displays, in perspective view, a cell that is a

variation on the cell of Fig. 10, reduced down now to just two parallel quartz laminas, acting in concert with a flexible light shutter bar that also acts to keep out moisture;

Fig. 12 shows a schematic longitudinal vertical section through just the parts and the circuits of a first form which the device can take, these being housed in a box support and bitten element;

Figs. 13A, 13B and 13C show, to larger scale, some variations of the circuits followed by the light rays, which leave the cells and finish up at the detector;

Figs. 14 and 15 show a schematic view from above, and cross-section x-x of Fig. 14 is through an improved bitten box element, and complete with cell;

Figs. 16 and 17 show two variations of a possible form for the box support and bitten element that includes two twin complexes for the reading, whether simultaneously or not, of the colour of the teeth in the upper or lower dental arches;

Fig. 18 schematically illustrates, in an exploded perspective view, a form in which a box support and bitten element are connected, removably, to a box for housing the remaining devices of the circuits of Figs. 1 or 2, for its replacement, with another element suited

to the kind of teeth the specific patient has.

Figs. 19A, 19B show respectively a vertical longitudinal section and a side view, partly in section, of the removable part of the complex of Fig. 18, suited for being used in two use positions;

Figs. 20 and 20A show a view of a flexible cable housing optical transmission fibers, that has a bitten device, this being a further variation of the invention;

Figs. 21 and 21A show a form of the invention with the light being transmitted through optical fibers, the former figure in vertical longitudinal section and the latter in horizontal section;

Figs. 22A, 22B, 22C are variations of the solution of Figs. 21 and 21A, but concerning only the detail of the application of a section converter, mounted at the end of the transmission optical fibers;

Figs. 23, 24 and 25 show vertical longitudinal sections of other circuit variations all using optical fibers;

Figs. 26A and 26B show a variation on the form in which the light is transmitted through optical fibers, but the detection of the tooth colour is effected by reflection; said figures representing, respectively, a vertical longitudinal section and a horizontal cross section of

the cable;

Fig. 27 shows a schematic partial horizontal section of one kind of spectrum-photometer device that includes an integrating ball and adapted to the invention's purpose;

Fig. 28 schematically shows, in a longitudinal vertical section, just the part of the spectrum-photometer device, including the ball and the bitten device, when it has been set up inside the patient's mouth;

Fig. 29 shows the vertical section got along line V-V of Figure 27, and

Fig. 30 shows an exploded view of the support device for the pair of cells housing the teeth, to be applied to the integrating ball so as to get the form the invention takes as shown in Figs. 27 and 29.

Referring to Fig. 1, the device comprises a light source (1), which sends a beam of light rays to a monochromator (2), which sends out monochromatic light rays to an optical switcher or chopper (3), that shunts the light rays into two parallel circuits (4, 5), by means of mirrors (13), mounted so as to be adjustable.
In circuit (4) the rays are guided by said mirrors so as to pass through a cell, generically indicated by (6), that can hold at least one of the patient's teeth (9), while the rays, guided in circuit (5), go through cell

(7), holding a reference white sample (28). The rays from the two output circuits (4A, 5A) are guided to a detector (8), such as a photocell, or photomultiplier or similar, that will supply signals for the two bundles of rays.

These signals are then amplified in the amplifier (11) and applied to an analogical-digital converter (12), which is hooked up to a data processor or computer (10), of well-known type and not shown, in which these signals are processed so as to extract the information in code of the colour had by the tooth (9) checked.

In the invention's variation of Fig. 2, the similar parts are indicated with the same numbers. In said variation a light source (1) is provided that, by means of an optical system of mirrors (13), these mounted so as to be adjustable for the purposes to be described in what follows, provides a beam of light rays that are sent into circuit (4), which includes the cell (6) for housing the tooth (9) and into circuit (5), which leads to the cell (7) holding the reference white sample (28), or other such as suitable.

The two light beams coming from the output circuits (4A, 5A) by means of an optical switcher or chopper (3) are brought to a monochromator (2), to then go on to the detector (8), are amplified in amplifier (11), and applied to converter (12), to then be carried on to the computer (10), according as described in the form of the invention referring to Fig. 1.

We shall now set forth in detail what the main

characteristics of a cell for housing at least one tooth (9) are, the colour of which tooth is to be detected and described in code.

Each cell (6), as noted, may be built so as to be able to detect the colour of one isolated tooth (9) or tooth with gaps separating it from the other teeth, or else of one or more teeth (9) where the teeth are set side by side, these being inserted in one cell only (6). A pair of separate cells (6A, 6B) may also be used, to detect the colour of two teeth superposed in the two dental arches, at the same time.

Cell (6) or cells (6A, 6B) comprise a housing having substantially the form of a U-cross-section channel, which is defined by an entry wall (6e), by an exit wall (6u) and by a bottom side (6f). Walls (6e, 6u) may lie parallel one to the other and have a cylindrical curvature, so that they may be adapted to the curvature of the dental arches of teeth (9), for which the colour must be detected. The rear wall (6u') could also be inclined to follow the anatomical form of the corresponding dental arch (as envisioned in Fig. 9B). Walls (6e) and (6u) or (6u') together with the bottom side, (6f), define a channel of rectangular cross section, having a depth and width substantially suited to the dimensions of the tooth or teeth (9) to be lodged in it.

The entry wall (6e) and the exit wall (6u or 6u') may be built of quartz crystal laminas cut perpendicularly to the optical axis, or may be made of some other suitable

equivalent material (Fig. 3). The bottom side (6f) may be made of any opaque material, or of quarz too, but lined outside with opaque material. The proportions of cell (6) may be adapted to specific tooth dimensions, as regards the tooth whose colour is to be detected. In this case, there would be a set of interchangeable cells. Or else there could be one universal cell, got using the expedients envisioned in the variations to be described herein. In Figs. 3 and 4 re and ru indicate the direction of entry and of exit of the axis of the light beam used.

In the variation of Figs. 5 and 6, 7A, 7B, a cell (6C) is envisioned, it being suited to the present case, i.e. of several teeth (9) side by side. Cell (6C) in that case has such length as to let at least three teeth (9) set side by side be housed in it (Fig. 7B).

It is envisioned in this variation that both the walls and bottom side (6a, 6f, 6u) be made of opaque material, while in walls (6e and 6u) (Fig. 6) two facing apertures are made (16e and 16u), through which the light rays enter and exit, after having crossed the tooth or teeth (9), the colour of which is to be detected and described in code.

An elastic shutter element is envisioned in this solution, to keep light and moisture from entering, which could otherwise penetrate from the sides and from above, in the area where the tooth being examined lies. The element (14) (in Fig. 5) comprises elastically deformable material such as rubber or similar, which is

shaped in the form of a longitudinal bar (Fig. 5); having a somewhat larger cross-section than the channel of cell (6C). In the central part of element 14 a crosswise aperture (18) is opened, having about the same dimensions as the apertures (16e, 16u) in cell (6C), while along the longitudinal midplane of the bar (14) a slot (15) is made (Fig. 5), having a width less than the minimum thickness envisioned for the teeth (9), which slot is open at the top, but stops somewhat before the inner face of bottom side (6f) of the bar (14).

Bar (14), owing to its elasticity, may be easily inserted by press-fitting into the channel formed inside cell (6C), having its form suited to the shape of the dental arch (Fig. 7A). At the time of use the patient's teeth (9) may enter in the slot (15), elastically displacing it toward the edge walls, which will therefore automatically close tightly around the teeth, and in particular around the teeth at the sides of tooth (9) (Fig. 7B), which is found between the apertures (16e, 18, 16u) and on which the colour detection will be made.

This solution is a very convenient one practically, since the elastic shutter element (14) costs little, so that it may be substituted and replaced with a new one for hygienical reasons after each operation, thus making cleaning and disinfecting the instrument easier too, between each patient.

In the variation of Figs. 8 and 8A, the cell of type 6D is designed to be used for a diastemic tooth, so that

the shutter element (15D) comprises a solid block (15D) having a cross aperture (18D) facing the center area of walls (6e, 6u), which aperture (18D) is prolongated at its top into groove (42) having a shape that makes it somewhat smaller that the cross-section of the tooth (9) to be colour-detected.

In the variation of Fig. 9A, where cell (6E) alone is illustrated, it is envisioned that walls (6e and 6u) of said cell (6E) are not made of quartz laminas, but simply of opaque material, like the bottom side (6f); they are however furnished with two longitudinal slits (43e, 43u), facing one another and made at the height of the optic axis re-ru.

Variation (6E') of the cell, seen in Fig. 9B, differs from cell (6E) only in that the rear wall (6u') lies at an inclination, like the dental arch.

In the variation of Fig. 10, cell (6F) comprises substantially only the shutter body (14), seen in Fig. 5, a body that will be held up at its sides by device (36, 36A) to be described in what follows, with reference to Fig. 18.

The light rays thus pass through the cross slot (18) and the tooth or teeth (9), while the bottom of slot (15) serves to support the tooth or teeth (9).

Finally, in the variation of Fig. 11, cell (6G) is formed, in combination, of a pair of quartz laminas (31), so sized as to block, one the cross entry aperture and the other the exit aperture of aperture (18), formed in the shutter body (14).

These laminas (31) will be inserted in the device's housing seats (31a), as will be described in what follows.

The reference cells (7) containing the white reference sample (28), are made in a simpler manner, having their front and rear walls as envisioned for cells (6), while they will have an opaque upper wall, bottom wall, and side walls. Clearly, reference cells (7) will always have identical dimensions, since they must only hold the reference sample (28).

Fig. 12 shows one form of the most characteristic part of the present invention, which part is lodged inside a shaped bitten element generically indicated with (19), which sticks out from a box (35), which houses at least devices (1, 2 and 3) of Fig. 1.

This element comprises a box-shaped body (20), made of metal or plastic, which is to be partially introduced into the mouth (21). In the specific case of its shape as seen in figure 1, lodged in the cavity inside the tubular body (20) are the two circuits (4, 4a and 5, 5a) as well as cells (6 and 7), and the detector (8). Cell (6) is inserted into an upper socket (20a) in element (20) its section being complementary to the cross-section of the central operating part of cell (6), which cell is arranged in such a manner as to have wall (6e) the entry, or grooves (43) arranged in such a manner as to let the beam of light rays from circuit (4), enter, in such a way that they may strike tooth (9), in this case this being a tooth in the patient's upper dental

arch, at about half its height. In correspondence with cell (6) and the housing socket (20a), element (20) is furnished with apertures to let said light rays enter into the cell (6) and to let them leave it (31a).

In the portion of wall of tubular element (20), opposite to that (portion) where socket (20a) is located that houses cell (6), the wall of element (20) displays undulations (22) or similar to facilitate its grip on the teeth (9) of the lower dental arch, so as to assure the exact positioning and immobility of the detection device during detection.

Around the end portion of tubular element (20), whose purpose is to be inserted into the mouth (21), upline of the area where cell (6) is, are mounted, these sliding along the outer surface of said element (20), two annular flanges (24A, 24B), made up of membranes of rubber or other material that can deform elastically, which are destined to be pushed toward the outside: one of them, (24A) against the lips (25) and the other, (24B) to be inserted between the patient's lips (25) and the dental arches (26). Flange (24A) is pushed against the lips (25) so as to prevent any light from entering the mouth (21) from outside.

Along the circuits or routes (4, 4a) and (5, 5a) taken by the light rays coming from device (3) as shown in Fig. 1 are inserted lenses (27) to guide the rays and to keep the rays' optic axis aligned along said circuits (4, 4a) and (5, 5a).

Before the rays enter cells (6 and 7) devices are

envisioned (29, 30) to get a bias voltage signal that is to be sent through circuit (40) to detector (8). Circuit (41) is the output circuit for detector (8), and it heads up at amplifier (11).

Figs. 13A, 13B and 13C show to larger scale the detail of the terminal tooth-clamping part of the tubular element (20), where cells (6 and 7) are inserted, together with detector (8), and a detail of the paths of the rays through circuits (4a, 5a), sent on the detector (8) and deflected through systems of mirrors (33) or of prisms (34).

Figs. 14 and 15 schematically show, in one view from above and in the cross-section X-X of Fig. 14, a variation of the tooth-clamping system, which must obviously be completed by flanges (24A, 24B) as illustrated in Fig. 12.

The body of the housing cell, in this case of type 6C, as shown in Figs. 5 and 6, which includes the elastic shutter element (14), envisioned to keep out outside light, is now furnished with a lower support (36) (see detail drawing of Fig. 18), made of a material that is only slightly elastic, such as rubber or similar; this body is attached to the lower wall (6f) of cell (6C) and, whose side walls (6e and 6u) are kept back and held up by the pairs of wings (36a), projecting up-wards. This body also has substantially the form of the dental arches (26).

This support (36) permits a solid grip on the teeth of the two dental arches (26) against body (20), and

permits the entry of the upper teeth into cell (6G), for the purpose of preventing any possible shift of the tubular element (20), which has to partially penetrate into the patient's mouth (21) as explained above.

Figs. 16 and 17 show two variations of the invention, suited to be used to detect the colour of one or more upper teeth and/or of one or more lower teeth.

In said Figs. 16 and 17 the same numbers are used to indicate equivalent parts, while being distinguished by the addition of a letter. In the variation shown in Fig. 16 the box support (20a) houses two complexes of devices substantially identical to the complex of devices forming the invention's operating part as seen in Fig. 12. But said two complexes are arranged symmetrically relative to the horizontal plane of symmetry Y-Y. In the upper complex, cell (6A) is open upwards and may be built according to any one of the variations envisioned, while (7A) is the cell for the reference sample (28), and (8A) is the detector. One complex, a mirror image, (6B, 7B, 8B) is to be found in the lower part.

To detect the colour of one of the upper teeth or of one of the lower teeth, the tooth (9) to be colour-detected in the upper dental arch will be lodged in cell (6A) and that one in the lower dental arch in cell (6B).

To determine the colour of a tooth of one dental arch, suitable means -- i.e. mirrors and interruptors -- will be used to cut out the other complex.

The variation of Fig. 17 is only a simplification of the solution shown in Fig. 16, its only difference being

that in element (20B) there is one cell only (7C) that houses the sample (28), and thus there is but one input circuit (5C) functioning alternately with the tooth being detected.

Fig. 18 shows a perspective, exploded view of a part of the device of the invention in which the box support for support (20) is envisioned as being separable from box (35), in which at least the devices (1, 2, 3) seen in Fig. 1 are housed. For this purpose, two sockets set side by side (38A, 38B) are made in box (35), their shapes being complementary to the shape of the entering end of box element (20), whose operating structure is built as shown in Fig. 12, but means are envisioned that will let it be inserted in socket (38A) of box (35), in such a manner that it can be put in and taken out again in the same position each time. In said Fig. 18 it is envisioned that the cell for housing the tooth or teeth to be detected will be of type (6G), that is, will be made up of but two quartz laminas (31), shaped in such a manner as to be inserted in housings (31a), made in correspondence to the apertures in the box element (20) that are facing socket (20a), as described and illustrated with reference to Fig. 11. Within socket (20a) and between laminas (31) the shutter body (14) will be inserted, as illustrated in Fig. 5, there then being mounted below said body (14) and below the part of box (20), underlying socket (20a), body (36), thus forming an element supporting and holding up body (14). Body (36) is outfitted with two sides pairs of parallel

tabs (36a), projecting upwards, their task to lock and to hold up the ends of the shutter body (14) that are projecting from box element (20). Shown in Fig. 18 too is a transverse anular flange (24A), which slides with some friction along the box body (20), and that is to be pushed up against the lips (25) after the patient's teeth (9) whose colour is to be detected, have been inserted in the groove (15) of the shutter body (14). (39) is used to indicate the laminas, collars or similar to be applied to box body (20) to facilitate the grip, when this body (20) must be inserted with its said end into housing (38A or 38B) of box (35), or taken out from it.

Figs. 19A and 19B show the details of the variation of the device for the case when two usage setups of box element (20) are called for, in detecting the colour of a tooth in the upper dental arch (Fig. 19A) or of a tooth in the lower dental arch (Fig. 19B), in the form as conceived and shown in Fig. 18.

For said purpose, as already noted, there are two housing set side by side (38A and 38B) in box (35). Housing (38A) has on its bottom side (38a) attachments for connecting up circuits (4, 5, 40, 41) where the device (20) must be used in its setup as shown in Fig. 19A, while housing (38B) calls for connections (38b) for device (20), when it is set up as shown in Fig. 19B, properly shunting the light rays along routes (4 and 5) by means of the adjustment of the positions of mirrors (13) in circuit (1), in such a fashion that they are led

to the connections of Fig. 19A or to those of Fig. 19B, and travel routes (40 and 41), by means of switches or other suitable means.

Figs. 20 through 25 inclusive concern a variation in which the circuits transmitting the beams of light are at least partly replaced by optical fibers.

In this case, the stiff box element used for the earlier forms of the device is, in the various type (20, 20a, 20b, 20c) replaced (see Fig. 20) by a flexible cable (44), which heads up on one of its ends at the grip part that is bitten, which is protected by a stiff box shell (45), in which at least one cell (6) is inserted, and that may or may not house cell (7), containing the white reference sample (28).

In the variation of Figs. 21, 21A, it is envisioned that in the cable (44) there is a socket for one cell (6) (6C, 6D, 6E, 6E', 6F, 6G), while inside cable (44) cell (7) for the white reference sample (28) and the detector (8) are mounted. (54 and 55) indicate the optical fibers leading to cells (6and 7).

Figs. 22A, 22B and 22C display variations similar to the one shown in Fig. 21A, in these Figures similar items bearing the same numbers used above for reference. The only difference is that the optical fibers (54 and 55), only the upper fiber (54) of which is visible, terminate with a section adaptor-converter (46), whose task is to output at least one beam having a line cross section, which may be either horizontal or vertical, this adaptor being located in front of one cell of type, for example,

(6C or 6G).

Inf Fig. 22A the output face of said adaptor (46) is plane and perpendicular to the optic axis. In this case, downline of adaptor (46) but upline of the tooth (9) a convex lens (not shown) may be mounted in proximity to cell (6), and downline of the tooth (9) another convex one (not shown) may be mounted, the former lens being to define the area of the tooth to be detected, and the latter to concentrate the rays on detector (8).

Fig. 22B shows the adaptor (46A) which still has a plane terminal wall, but penetrates inside the cell, which is of type (6E or 6E'), passing through slit (43e) called for in wall (6e). Fig. 22C is similar to Fig. 22B, but displays an adaptor (46B) having a concave terminal face so as to be better adapted to the front profile of tooth (9), together with a suitable lens downline of the tooth.

In the variation of Fig. 23, flexible cable (44A) holds only the two circuits for cells (6 and 7), while the detector is housed in box (35). Indicated by (54, 54a) are two sections of optical fiber guiding the light rays to cell (6) and that receive them on their output from this cell. Similarly, (55, 55a) are the two branches of optical fiber that concern cell (7).

In the variation of Fig. 24, cable (44B) and the bitten support (45B) are there to house the same elements, as in Fig. 23, the difference being that, in order to reduce the size of cable (44B), the two return branches are formed, at their ends, of rectilinear optical fibers

(54a and 55a), but the curved sections are eliminated, these being replaced by paths got by means of a system of mirrors (47, 47). This solution lets the cable (44B) dimensions be reduced, since the optical fibers are no longer curved, and as is known, they may not have small "radii" of curvature.

The variation of Fig. 25 is the simplest of the variations proposed, since in this case cable (44C) is used to hold only cell (6) and the two truncated ends of optical fiber (54, 54a) belonging to that cell, while cell (7) holding the reference sample is to be found inside box (35), as seen in the scheme of Fig. 2.

Figs. 26A, 26B, show another variation of the form of the invention in which optical fibers are used to convey the light rays.

This variation concerns the case in which cable (44D) together with the part inserted in the mouth (45D) is prepared for detecting the colour of teeth both in the upper dental arch and in the lower one, cable (44D), as may hold true for the earlier cases too, may be hooked up permanently to box (35), or there may be attachments to make it removable.

In this variation however it is envisioned that light ray impulses are sent to cells (6A, 6B) that are used to hold teeth (9) in the two dental arches, by means of optical fibers (48A and 48B) respectively, so as to hit the teeth (9) under detection right in their center, said rays being reflected from these teeth and sent back along the same fibers to be shunted into a detector,

housed in box (35).

Same thing holds true for cell (7), holding the reference sample (28), on which the light impulse conveyed through the optical fiber (49) is reflected, and which, then conveys the reflected light.

In this form of the invention, which derives from the variation, in which the use of only one sample cell (7) is envisioned, the optical fibers (48 and 49) are furnished with concave terminal surface section converter (46B).

In this form shown in Figs. 27 and 28, as in the one shown in Fig. 26A, it is envisioned that the light impulse be reflected as before from each tooth (9) considered, as holds true too for the white reference sample, but with the use of an integrating-ball spectrum-photometer.

Fig. 27 schematically shows a spectrum-photometer (50) of a kind already known, in particular of UV/VIS type, which includes said integrating ball (51), which may or may not be outfitted with two flattened opposite paralallel parts (51A and 51B). Said spectrum-photometer (50) is housed inside a case (52) that, as shown in the form shown in Fig. 27, is prolonged to form a side appendage (52a), whose task is to hold said ball (51), in such a manner that its flattened part (51B) is accessible through an aperture (53) in the head of the appendage (52). In the rear flat portion (51B) of the ball (51) these are two openings (56A, 56B) (see Figs. 28, 29) lying one atop the other, divided by a portion

of wall (60), and in said plane portion (51B) a socket is hollowed out that takes the white reference sample (28). Openings (56A, 56B) are so proportioned and arranged as to lie directly before the central area of teeth (9) set into cells (6FA, 6FB). In the opposite flat part (51A) of ball (51) three apertures are called for (57A, 57C, 57B), these being in optical alignment with aperture (56A), with the reference sample (28) and with aperture (56B) respectively.

A support (58, 58A) is attached to the center part of the flat portion (60) of the rear wall (51B) lying between apertures (56A and 56B).

Said support (58) is extended upwards to become a pair of front side tabs (58aA) and a rear tab (58bA), and extends downwards to become a pair of front tabs (58aB) and a rear tab (58bB). Said support (58), together with said tabs forms the two cells (6FA and 6FB) respectively, whose task is to hold at least one tooth (9) of each of the two dental arches, with the interposition of the respective shutter element (14A, 14B), which elements are built according to the characteristics already set forth for the shutter element (14, 15D) already explained. Furthermore, considering the special type of reflected-ray control, the center openings (18A and 18B) of the shutter elements (14A and 14B) are arrested at their meeting with the rear faces (15a, 15b) of slots (15A, 15B).

In this form of the invention, in order to keep outside light from entering the colour-detection area, on the

outer face of ball (51), located near the rear flattened part (51B), at the point where the patient's lips are to be supported, there are to be applied plastic or rubber or similar material laminas, that may be changed so as to obtain a good seal for the lips (25) on said parts.

In this form of the invention the light rays enter at alternate times from apertures (57A and 57B and 57C), striking through apertures (56A, 18A) to hit an upper tooth (9), and through apertures (56B, 18B) to hit a lower tooth (9), being then reflected from the special interior surface of ball (51) so as to strike, after successive reflections, detector (61), while the rays penetrating through aperture (57C) alternately strike reference sample (28) and then, after successive reflections, detector (61), according to the scheme: upper tooth - reference white, and lower tooth - reference white, proceeding as already described above. The control systems for making the two color detections are identical to those described above, that is mirrors (33) and switches.

The variation shown in Fig. 20A comprises the integrating ball located at the end of cable (44), it too functioning by means of optical fibers.

Another variation, not shown in the figures, comprises a smaller ball, containing only one cell (6) and one cell (7), which can be used to colour-detect the upper incisor-teeth, it being outfitted with a system similar to that of Figs. 19A and 19B, which will also let the lower teeth be colour-detected.

Another variation, not shown in the figures either, uses the reflection of the rays into an optical system of mirrors that convey the reflected light directly into the detector inside the spectrum-photometer.

CLAIMS

1. A device for the determination of the colour of one or more teeth, so as to obtain a dental prosthesis or dental filling or reconstructed tooth having a colour identical to the neutral tooth, using a UV/VIS spectrum-photometer, which device is characterized by what it comprises: a light-source (1), a monochromator (2) that applies the rays to an optical switcher or "chopper" (3), which, through mirrors (13) whose positions may be adjusted, feeds two parallel light-ray circuits (4, 4a; 5, 5a), a cell (6) being inserted in the first of these that is open either above or below and that can take at least one tooth (9), and is outfitted with such means as will let light rays enter, let them pass across the tooth (or teeth) (9) and let them exit, and with means that will keep stray light and moisture out of the remaining parts, while in the other circuit (5, 5a) a cell (7) is inserted containing the white reference sample (28), and a detector (8) such as a photocell, a photomultiplier or similar that receives the signals arriving from circuits (4, 4a, and 5, 5a) and compares them, an amplifier (11) that amplifies the signal got, an analogical-digital converter (12) that applies said signal to a data processor or computer (10) which outputs coded data of the colour so detected.

2. A device as in claim 1 in which the device comprises, as an alternative, upline of the detector (8) a light

source, an optical system of adjustable mirrors (13), whose task is to supply light rays that are sent into two parallel circuits (4, 4a) and (5, 5a), which circuits respectively include a cell (6) and a cell (7) containing the reference sample (28), the output branches (4a, 5a) of said circuits heading up at an optical switcher or "chopper" (3) that sends the rays on to a monochromator (2), which rays are then applied to the detector (8) and then to device (11, 12, 10).

3. Device as in claim 1, in which the cell (6) is formed of a longitudinal channel element delimited by an entry wall (6e), by an exit wall (6u) and by a bottom side (6f), those parts at least of the walls (6e, 6u) near to the optical axis of the light beam being made of quartz laminas cut normally to the material's optic axis, while the bottom side may be opaque or may itself be of quartz with an outer opaque lining, the cell's (6) transverse dimensions being in proportion to the dimensions of the tooth or teeth (9) whose colour is to be detected, while the cell's (6) lenght depends on the number of teeth (9), - three prefereably - to be lodged in it.

4. Device as in claims 1 and 3, in which the cell (6a) is prepared to contain several teeth (9) and in whose walls (6e, 6u or 6u') there are formed apertures (16e, 16u) in correspondence with the entry and exit of the light rays, while in the U channel defined by the walls (6e, 6f, 6u or 6u') there is removeably inserted a shutter element against light (14) formed of a bar having a cross section complementary to the cell's

channel's, but somewhat larger, which bar is to be made of some elastically deformable material, and is furnished crosswise with an aperture (18) in alignment with, and substantially identical to, apertures (16e, 16u) of the walls (6e, 6u, or 6u'), there being furthermore in the bar (14) a longitudinal vertical slit (15) opening towards the outside that is prolonged towards the bottom side (6f), and being arrested shortly before it, having a width less that the minimum thickness of each tooth (9) to be colour-detected.

5. A device as in claims 1, 3, 4 in which the cell (6C) is formed of just shutter body (14, 15, 18).

6. A device as in claim 1, 3, 4, in which the cell (6D) is formed in combination of just two parallel laminas (31) of quartz, to be applied against the mouths of the two apertures (18) of a shutter body (14, 15, 18).

7. A device as in claim 1, in which there is envisioned a box (35) assigned to holding at least the contrivances placed upline of the two circuits (4, 4a) and (5, 5a), while these circuits and the detector (8) are housed in a rod-shaped box element (20) connected to the box (35) and so dimensioned as to be able to be introduced, with its outermost end, into the patient's mouth (21), element (20) in which there is a socket (20a) for housing, in a replaceable or partially replaceable manner, a cell (6, 6C, 6D, 6F, 6G), that projects from the sides of said socket, having a cross-section complementary to the cross section of said cell (6), and which is furnished with apertures in its parts facing

the walls (6e, 6u), while inside said box element (20) the cell (7) is inserted, it holding the reference sample (28), and there being able to provided lenses (27) to guide the light rays along the entry branches (4, 5) of the circuits (4, 4a, 5, 5a), and mirrors or prisms (33, 34) to guide the rays in the output branches (4a, 5a) so as to make them hit the detector (8), from said circuits (4 and 5) there being able to be offtaken synchronization signals that can be applied, by means of circuits (40) to said detector (8).

8. A device as in claims 1 and 7 in which in correspondence to the socket (20) that houses a cell (6, 6c, 6D, ...) there is applied to the box element (20) a support body, (36) that is partly arranged below element (20), and is prolonged along the sides of this, in such a manner as to support the side parts of said cell (6), which project from element (20), which cell is tightly held along its sides by pairs of tabs (36a), said support body (36) being made of somewhat elastic material such as hard rubber or similar.

9. A device as in claims 1 and 7 in which the element (20C) is connected to the box (35) and by a demountable arrangement can be held up, by means of its end portion, at the point opposite to that bitten, within a complementary cavity (38) in box (35) and having such a depth as is suitable, and in whose bottom face (38a) are provided the attachments for hooking up with the device's fittings.

10. A device as in claims 1, 7 and 9, in which in box

(35) there are envisioned two cavities set side by side (38A, 38B) in the bottom side (38a) of one of which there are hookup attachements for inserting the box element (20C) into the system, in which cell (6) is open upwards, and in the other, the hookup attachments for element (20C) into the system in which cell (6) opens downwards.

11. A device as in claims 1 and 7, in which the box element (20a) comprises two identical twin operational complexes, these being arranged in mirror images one of the other relative to the horizontal plane of symmetry (Y-Y), in such a manner that said element (20a) be outfitted with a cell (6A) opening upwards, and whith a cell (6B) opening downwards, to permit the colour detection on teeth (9) in the one or the other dental arch.

12. A device as in claims 1, 7 and 11, in which the box element (20b), is so arranged as to contain two twin detection systems being opposed in mirror image relative to the horizontal plane of symmetry (Y-Y) of the box element (20b), but, in which there is inserted but one cell (7C) for housing the reference sample (28), which is used alternately by the two detection systems, while the detection device (8) is single.

13. A device as in claims 1 through 6, in which there is envisioned a flexible cable (44, 44A, ...) for housing at least the circuits , which head up at the cell or cells (6), and which are built, at least partly, of optical fibers, which cable, hooked up permanently or

detachably to box (35), which houses at least a part of the devices components, said cable being outfitted with a stiff lining (45, 45 A, ...) in the biting areas, which includes a socket for each cell (6) for detection envisioned.

14. Device as in claims 1 through 6 and 13, in which the cable (44) holds the optical fiber (54) that guides the light rays to cell (6), the optical fiber (55) that guides the light rays to cell (7), holding the reference sample (28), and the detector (8); said fibers (54, 55) being able to be outfitted at their ends with section adaptors-convertors having plane end faces (46, 46A) or concave end faces (46B), one part of the branches of the optical fibers (4a, 5a) being able to be replaced by mirrors (47).

15. Device as in claim 1 through 6 and 13, in which the cable (44A) holds only the optical fibers (54, 54a) and (55, 55a) and their respective cells (6 and 7).

16. Device as in claims 1 through 6 and 13, in which the cable (44C) holds only the cell (6) and its optical fiber circuit (54, 54a).

17. Device as in claims 1 through 6 and 13, in which the cable (44D) holds the optical fibers (48A, 48B) that lead to the two cells (6A, 6B) mounted one atop the other and mirror images one of the other, and the optical fiber (49) heading up at cell (7) holding the reference sample (28), there being envisioned means for receiving, through these same optical fibers (48A, 48B, 49) as well the optical signals deriving from the

reflection of the light impulses sent onto the teeth (9) and onto the reference sample (28), and by these two reflected, and for then applying the impulses to the detector (8), housed inside box (35).

18. Device as in claim 1, in which the spectrum-photometer is of the integrating ball type, outfitted with apertures for letting the rays fall on the reference sample and on at least one areola of the object on which information as to its colour is to be gathered, and with apertures for letting the light rays enter, which apertures are optically aligned with the preceding apertures, which ball is connected to the detector device, characterized by the fact that said ball (51) is inserted into an appendage (52a) of a box (52) housing the spectrum-photometer components (50), a box outfitted with three apertures (57A, 57B) and (57C) for letting the light rays enter, these apertures being arranged vertically, while in the plane wall portion diametrically opposite (51B) of said ball and in optical alignment with said apertures (57A, 57C, 57B) there are envisioned, still in vertical alignment: an aperture (56A), a portion of wall (60) on whose rear surface inside the ball there is a socket (56C) to hold the reference sample (28), and an aperture (56B); said apertures (56A, 56B) being arranged in front of two cells (6FA, 6FB) held up by a support device to be bitten (58), attached to the rear face of the portion (60), of the wall (51B), behind the socket (56C) in the integrating ball (51).

19. A device as in claim 18, in which the support and device that is bitten holds a central body (58) having rectangular cross section and has longitudinally cylindrical walls, having such a shape as to be suited to the shape of the dental arches, and that is made of a slightly elastic material such as hard rubber or plastic, which body (58) is prolonged upwards and prolonged downwards, in such a manner as to form two U-channels symmetrically opposite relative to the horizontal plane of symmetry, which channels are defined frontwide only laterally by two pairs of upper anterior tabs (58aA), and lower anterior tabs (58aB) and by a single rear upper tab (58bA) and a single rear lower tab (58bB), so as to form respectively cells (6FA, 6FB) in which are inserted the shutter elements (14A, 14B), outfitted with longitudinal slots (15A and 15B) and with an aperture (18A, 18B) that crosses only the side of the element (14A, 14B) and that faces the apertures (56A and 56B), and having the same shape and dimensions.

20. A device according to claim 13 in which the flexible cable (44, 44A, ...) holds up the integrating ball (51) at its end.

21. A device according to claims 13, 19 and 20 in which the device comprises an integrating smaller ball, containing only one cell (6) and one cell (7), which can be used to colour-detect the upper incisor teeth.

22. A device according to claims 1, 6 and 19 in which the device uses the reflection of the rays into an optical system of mirrors that convey the reflected

light directly into the detector inside the spectrum-photometer.

FIG. 1

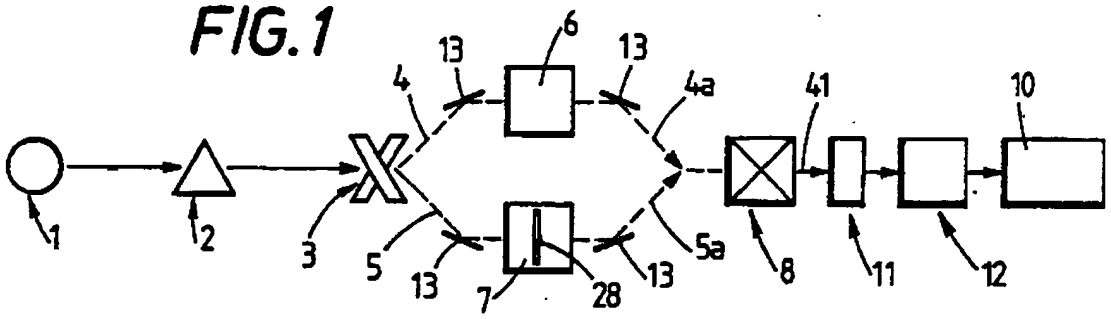


FIG. 2

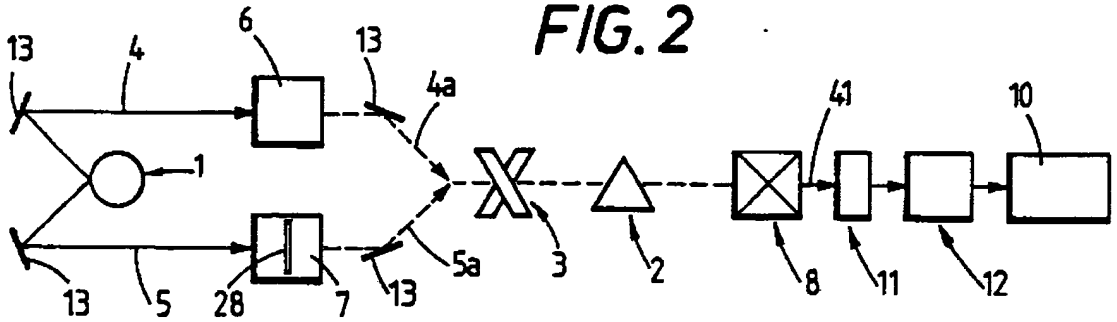


FIG. 3

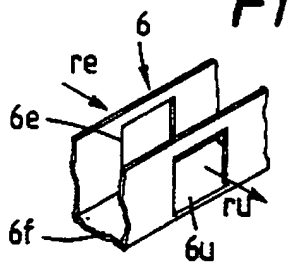


FIG. 4

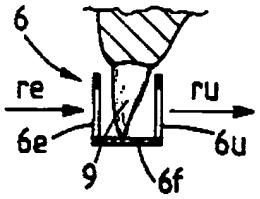


FIG. 5

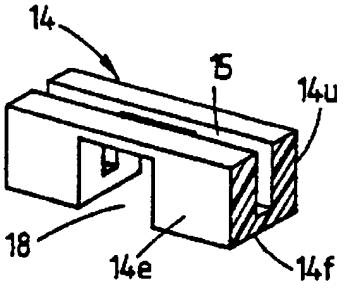
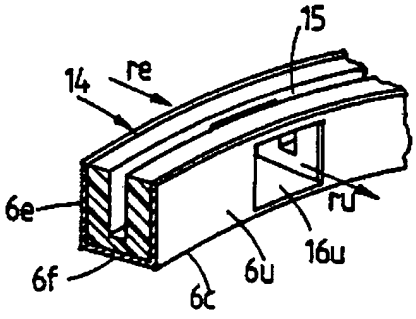


FIG. 6



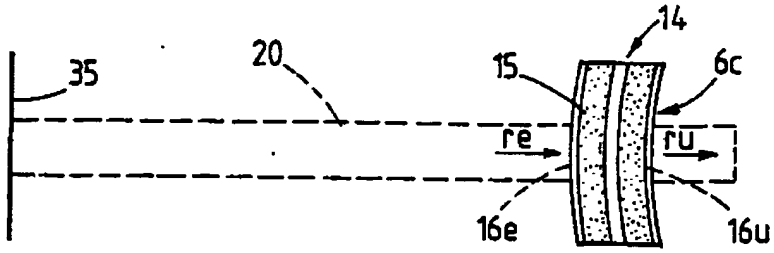


FIG. 7A

FIG. 7B

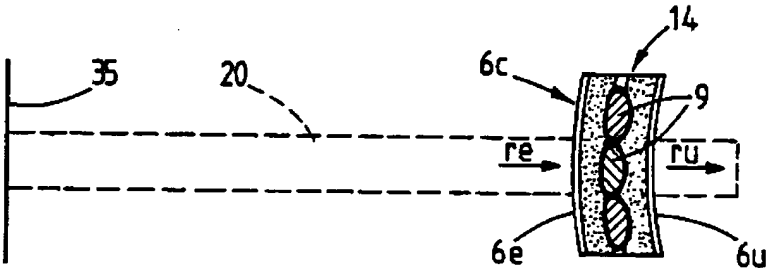


FIG. 8

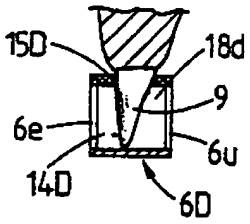


FIG. 9A

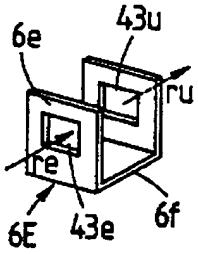


FIG. 10

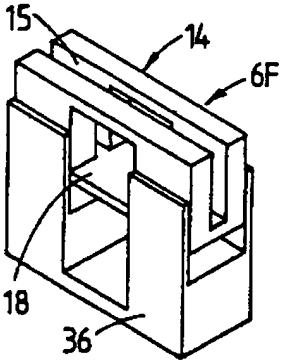


FIG. 8A

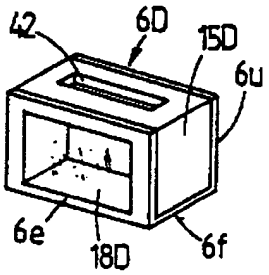


FIG. 9B

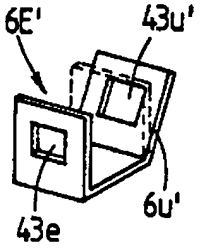
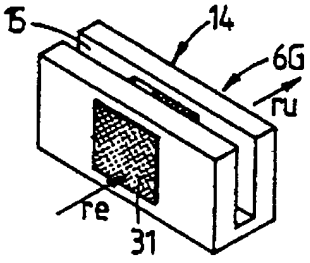


FIG. 11



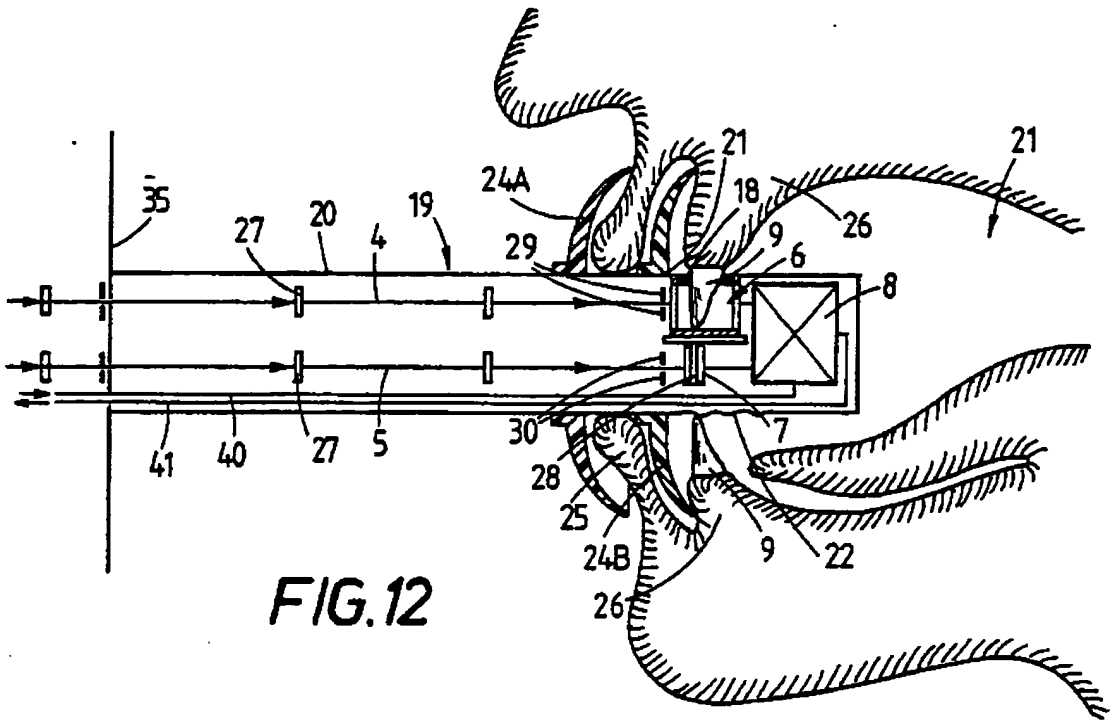


FIG.12

FIG.13A

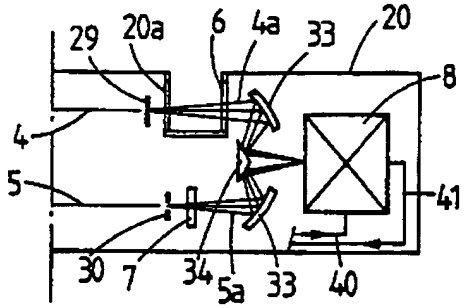


FIG.13B

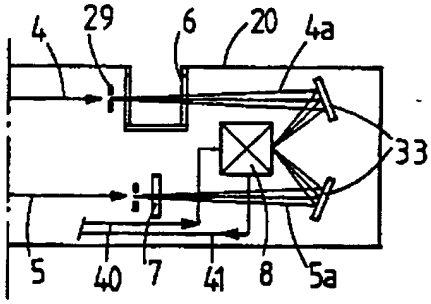


FIG.13C

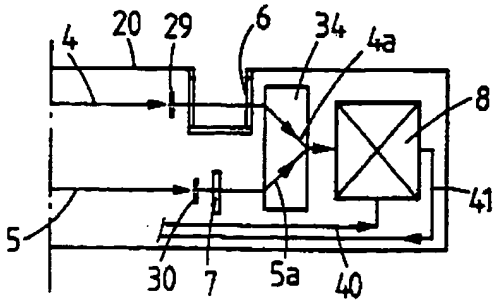
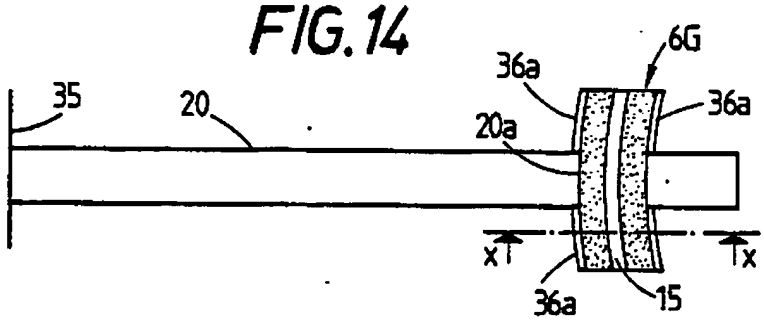


FIG. 14



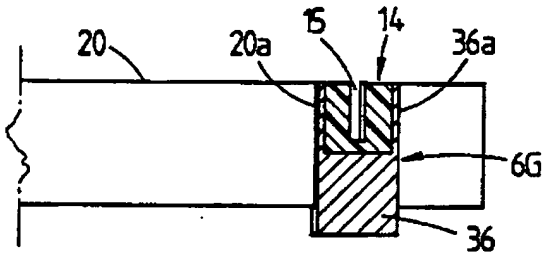


FIG. 15

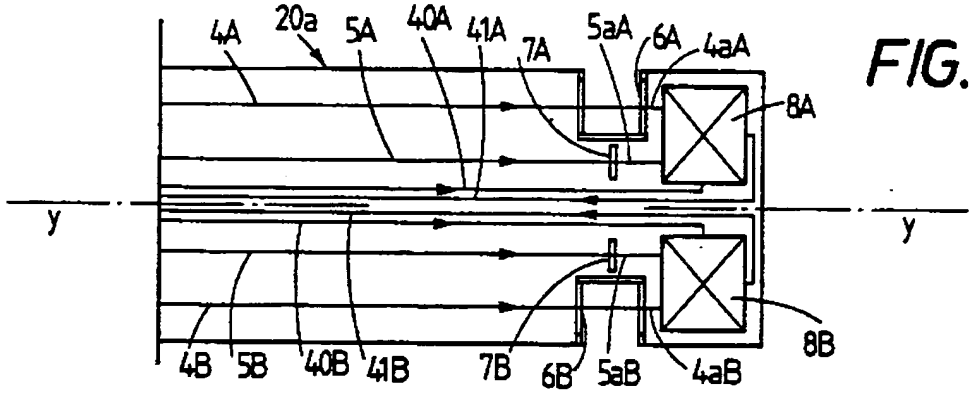


FIG. 16

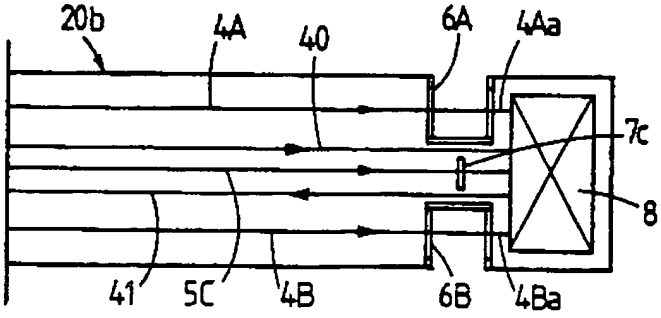


FIG. 17

FIG. 18

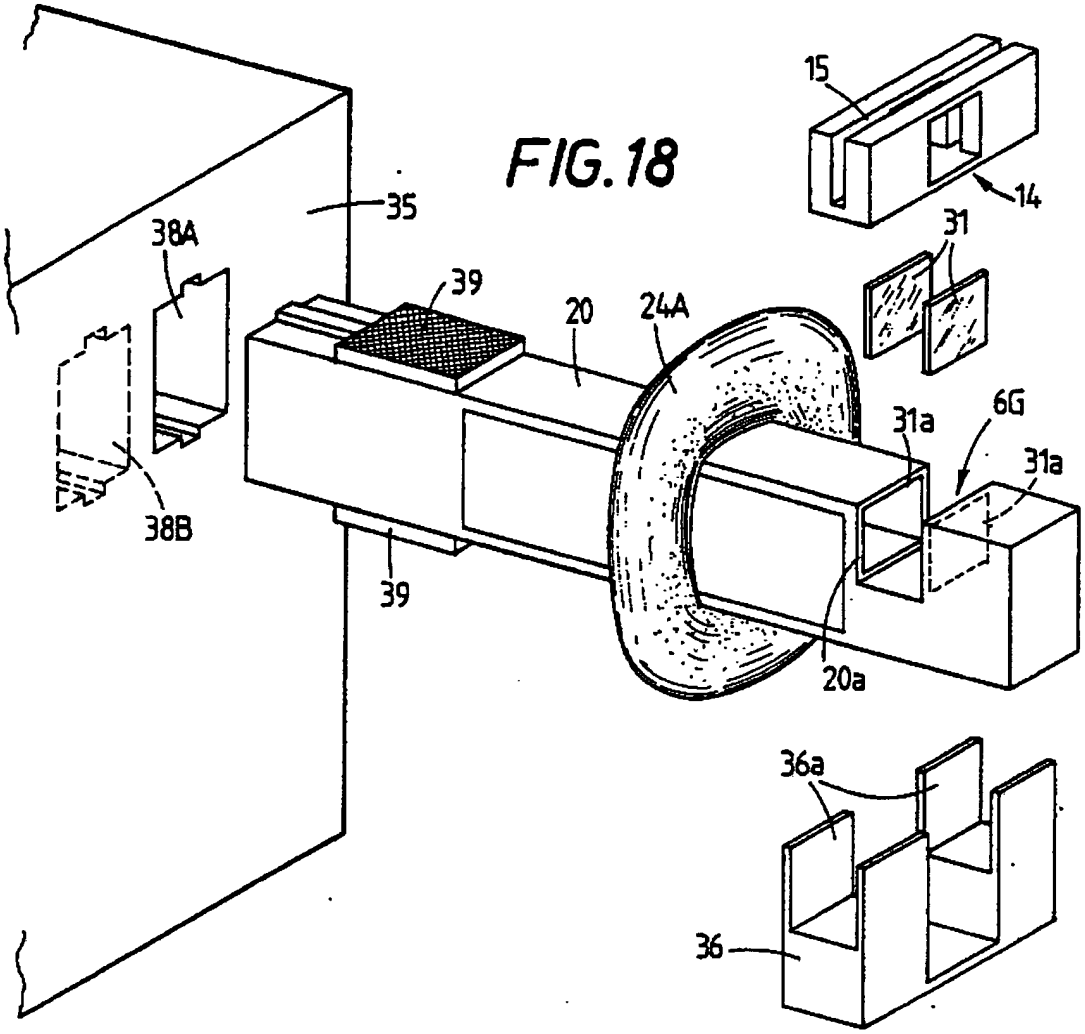


FIG. 19A

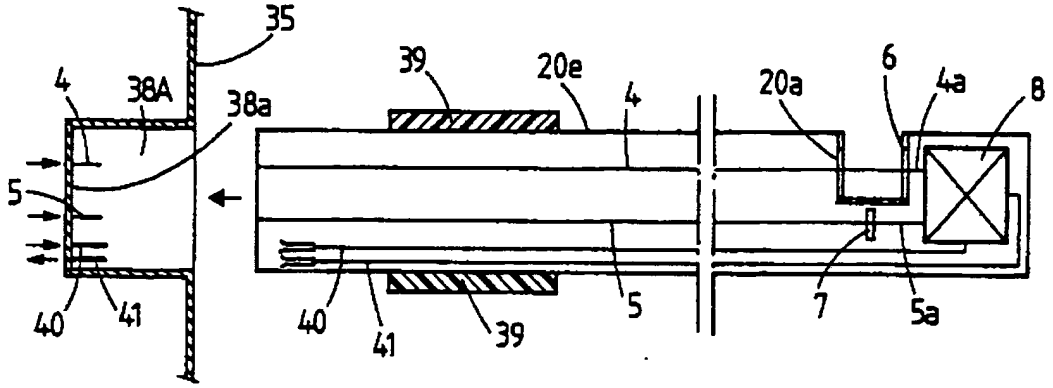


FIG. 19B

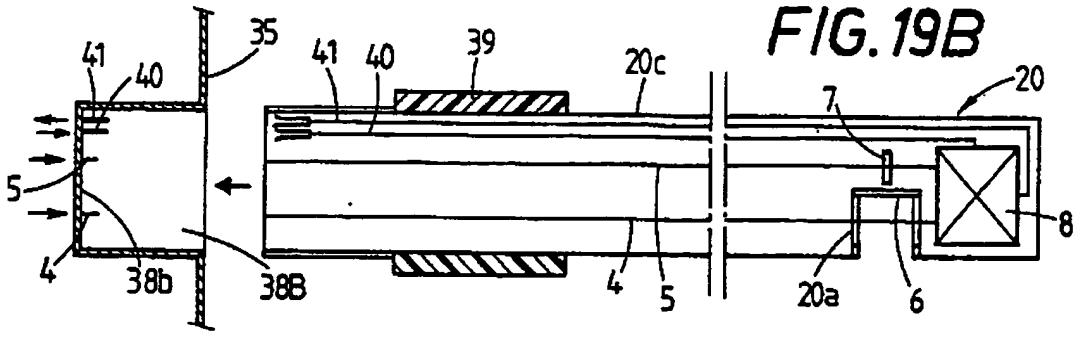


FIG. 20

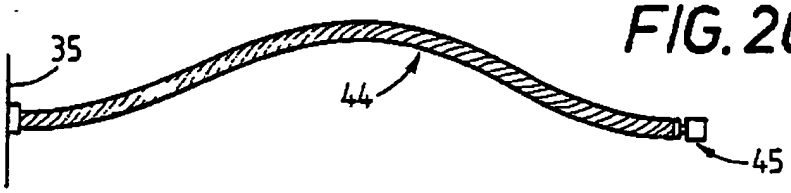
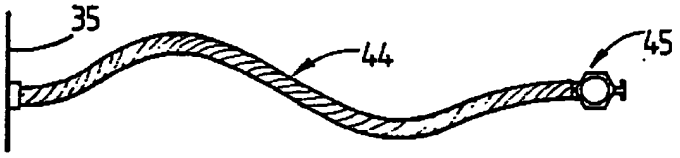


FIG. 20A



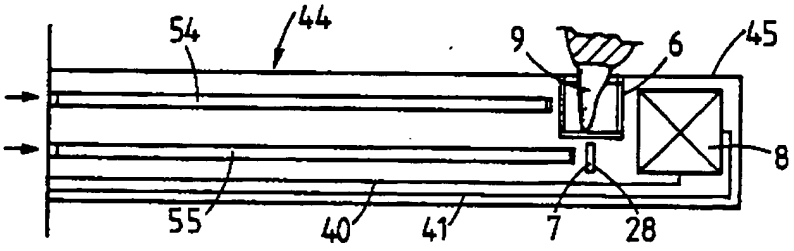
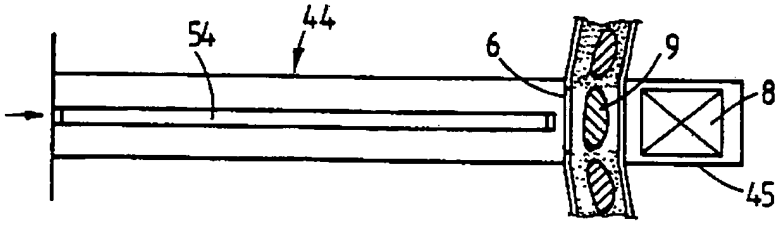


FIG. 21

FIG. 21A



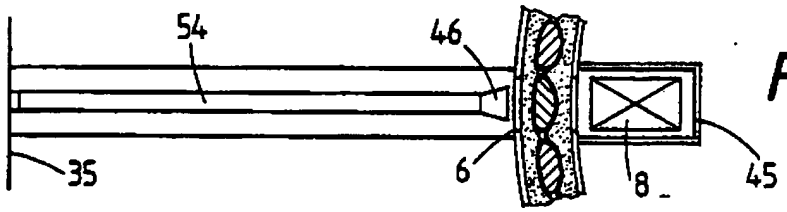
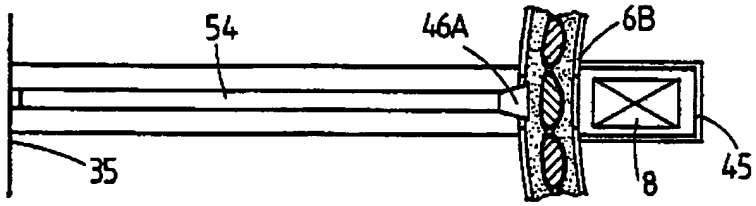


FIG. 22A

FIG. 22B



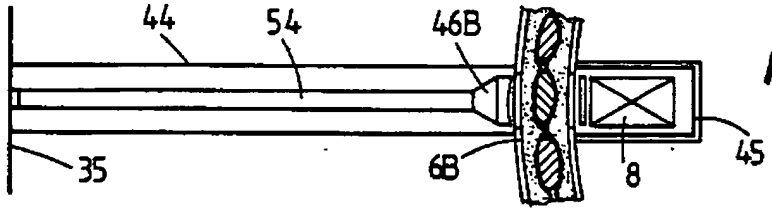
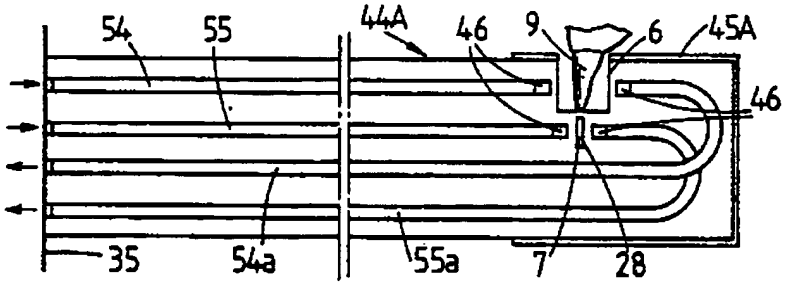


FIG. 22C

FIG. 23



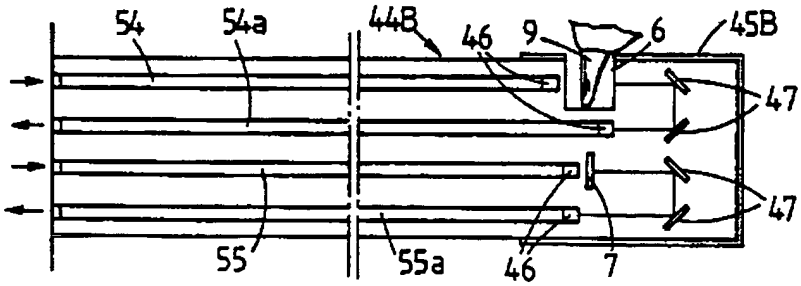


FIG. 24

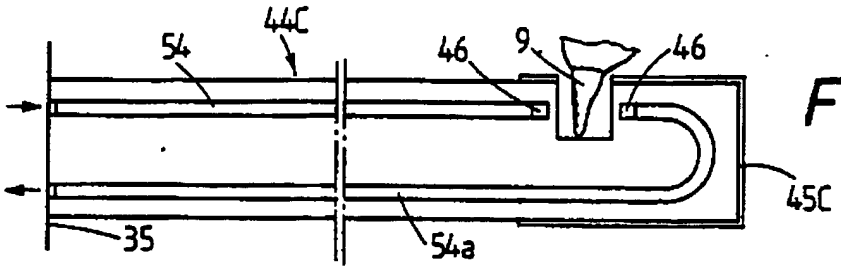


FIG. 25

FIG. 26A

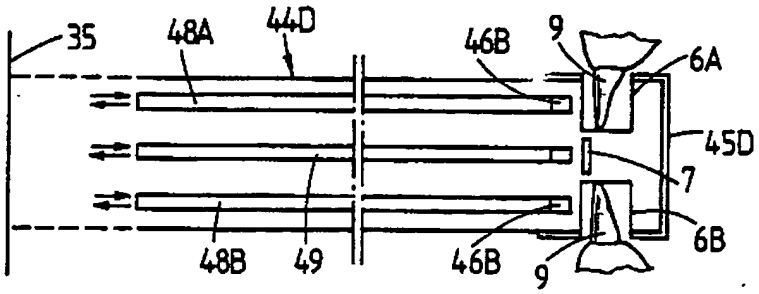
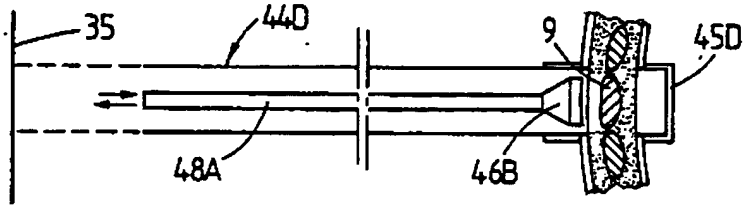


FIG. 26B



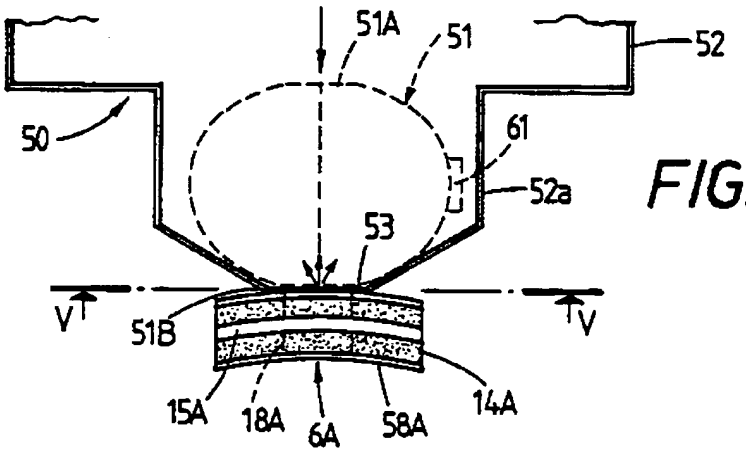


FIG. 27

FIG. 28

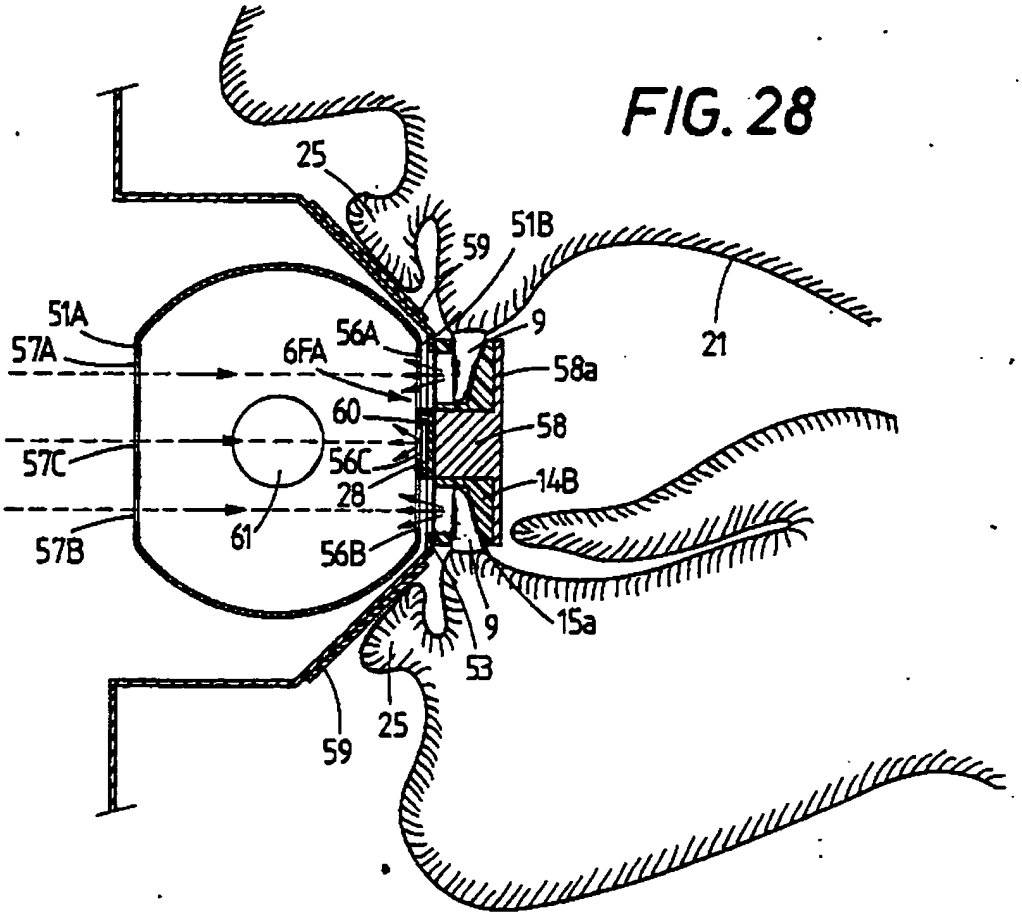


FIG. 29

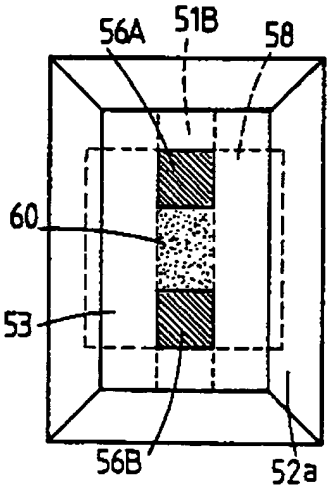
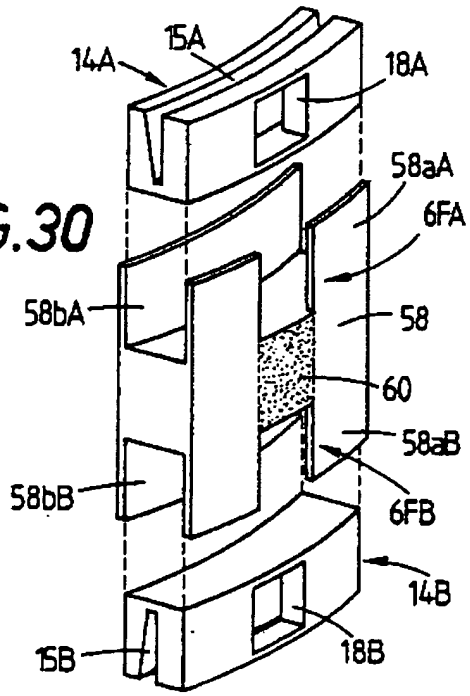


FIG. 30



INTERNATIONAL SEARCH REPORT

International Application No PCT/IT 85/00046

I. CLASSIFICATION OF SUBJECT MATTER (if several classification symbols apply, indicate all) [6]

According to International Patent Classification (IPC) or to both National Classification and IPC

IPC[4]: G 01 J 3/50; A 61 C 13/08

II. FIELDS SEARCHED

Minimum Documentation Searched [7]

Classification System	Classification Symbols	
IPC[4]	G 01 J 3/50	A 61 C 19/00
	G 01 J 3/46	A 61 B 1/24
	A 61 C 13/08	G 01 N 21/25

Documentation Searched other than Minimum Documentation to the Extent that such Documents are included in the Fields Searched [8]

III. DOCUMENTS CONSIDERED TO BE RELEVANT [9]

Category [10]	Citation of Document, [11] with indication, where appropriate, of the relevant passages [12]	Relevant to Claim No. [13]
A	US, A, 4468197 (W. PROVOST) 28 August 1984, see column 3, lines 26-60; column 4, lines 12-48; column 6, lines 39-50; claims 1-4,10; figures 1-3	1,7,13
A	FR, A, 2188157 (W. SWINSON) 18 January 1974, see page 4, lines 20-33; page 5, lines 1-24; figure 2	1,13
A	US, A, 2437916 (W. GREENWALD) 16 March 1948, see column 2, lines 28-51; figure 1	1
A	US, A, 4125329 (P. FRENCH et al.) 14 November 1978, see column 6, lines 21-36; figure 2	1
A	DE, A, 3045162 (P. HEITLINGER et al.) 1 July 1982, see page 5, lines 13-26; page 7, lines 1-7; figures 1-2	1
A	Patents Abstracts of Japan, volume 5, no. 64, 30 April 1981, pages 59-736 & JP, A, 5616846 (HITACHI SEISAKUSHO) 18 February 1981, see the whole document	1

* Special categories of cited documents: [14]

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"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

IV. CERTIFICATION

Date of the Actual Completion of the International Search	Date of Mailing of this International Search Report
11th February 1986	06 MARS 1986
International Searching Authority: EUROPEAN PATENT OFFICE	Signature of Authorized Officer: M.VAN [illegible]

Form PCT/ISA/210 (second sheet) (January 1985)

ANNEX TO THE INTERNATIONAL SEARCH REPORT ON

INTERNATIONAL APPLICATION NO. PCT/IT 85/00046 (SA 11328)

This Annex lists the patent family members relating to the patent documents cited in the above-mentioned international search report. The members are as contained in the European Patent Office EDP file on 21/02/86

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Patent document cited in search report	Publication date	Patent family member(s)		Publication date
US-A- 4468197	28/08/84	EP-A-	0123548	31/10/84
FR-A- 2188157	18/01/74	DE-A-	2256355	13/12/73
		JP-A-	49027096	11/03/74
US-A- 2437916		None		
US-A- 4125329	14/11/78	DE-A-	2739794	16/03/78
		FR-A-	2363789	31/03/78
		US-A-	4131367	26/12/78
		JP-A-	53051785	11/05/78
		CA-A-	1086981	07/10/80
DE-A- 3045162	01/07/82	None		